Research and Development in some Benelux Firms

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Onderzoeksrapport Nr. 7203

C O N T E N T S

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Introduction

The definition of research and development under which we proceed in this study comes from the U.S. National Science Foundation ; thus are included basic and applied research in the sciences and in engineering and design and development of prototypes and processes. Are excluded : quality control, routine product testing, market research, sales promotion, sales service, research in the social sciences or psychology or other nontechnical services or nontechnical activities. The aim of basic and applied research is the creation of new knowledge. Applied research has the further goal of leading to a pay-off. Development work is aimed at the application of research findings to new or improved products and processes [1].

Research laboratories with the aim of improving a firm's position in the market were created in the U.S. early in this century. Europe followed later. The objective of this study was to gather information with respect to the organization and programming of Research and Development in Benelux firms [2].

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This study was sponsored by the Commission of the European Economic Communities.

1) E. MANSFIELD : The Economics of Technological Change : Chapter 3 ; Industrial Research and Development.

2) From here on abbreviated as R. and D.

The firms have been selected to cover a broad range of industrial activity : several branches of the chemical and allied industries ; the electronics and communication industry ; the steel industry and metal products industry and a service industry.
Of the ten firms interviewed, eight had organized R. and D. departments. Two of these eight firms were Dutch, the other Belgian. All except one had a sales figure of over 5 billion Belgian francs.

The firms were visited by a two to three-man team for extensive interviews. These interviews took place with top management, with the direction of R. and D. and sometimes with persons who were leading divisions. Questions were asked in accordance with an operating scheme worked out in advance. The taking of notes during the interview was kept to a minimum. Additional information was obtained by questionnaire near the end of the study.

We have divided the report in three parts. In part I, we discuss the magnitude of the R. and D. effort in the firms visited. Part II deals with their R. and D. policies and strategies. Part III finally is devoted to the selection and evaluation of research projects.

PART I. THE R. AND D. EFFORT IN SELECTED FIRMS

In this part, we shall proceed from a consideration of the criteria for measurement of the R. and D. effort to the presentation of our findings, followed by a discussion.

§ 1. Criteria for the measurement of the R. and D. effort

Several criteria can be used for comparing firms as to their R. and D. effort. The most frequently cited criterion is the annual R. and D. budget expressed as a percentage of sales. A comparison on this score is not without danger. Suppose a firm **X** has been absorbed by a holding company composed of similar firms to which firm X is selling licences. Then measuring the R. and D. effort of X versus its own sales figure will result in a high percentage ; measurement versus all sales of products due to research by X will result in a more correct picture. We have, if necessary, and as far as possible used the latter criterion. The percentage cited could of course fluctuate from year to year. Major increases from period to period could occur if a firm has just started with a R. and D. activity. The firms selected for this study had formally or informally gone through a research experience of at least fifteen years [1)]. Also, the particular method of fixing the R. and D. budget adds in many cases to the stability of this ratio (see later) so that the data reported in table 1 (year 1969) can be taken as sufficiently representative of the R. and D. effort according to this criterion.

A second criterion for the comparison of R. and D. efforts is the absolute or relative number of employees for this function. Using absolute number

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1) with one exœption.

of employees leaves out of consideration the dimension of the enterprise. The criterion of relative number of employees suffers from the fact that all industries are not equally labor or capital intensive.

The total expenditure devoted to R. and D. is again an absolute criterion and such is the number of patents taken annually. However, how many patents have been obtained is not only dependent upon the amount of research but also on the nature and scope of the innovations and the particular patent policy followed.

Probably the best measure for comparing relative research intensity is the R. and D. budget expressed as a percentage of sales, whereas total R. and D. efforts can be gauged according to the size of the R. and D. budget.

§ 2. Data and interpretation

In table 1 (p. 5) have been collected data bearing upon the magnitude of the R. and D. effort.

The reader will note a very regular relationship between the absolute number of personnel in R. and D. and the absolute R. and D. budget. This regularity is reflected in the rather constant ratio of column (5) and is not surprising if one knows that generally 80 % of the R. and D. budget consists of salaries. The same regularity does not hold when one compares relative number of personnel versus the R. and D. budget expressed as a percentage of sales. Indeed, these relative figures do take into account the degree of capital or labor intensity of the industries. Even after selecting firms out of relatively research intensive industries, significant differences in research efforts persist across industries. First of all, industries differ significantly with respect to the value the consumer

Table 1. Data with respect to R. and D. effort in selected firms

(1) Firm no.	(2) Formal team	(3) Personnel in R. and D.			(4) Investment in R. and D.		(5) Ratio investment in R. and D.
		absolute	% total	% univ. graduates	absolute (in million B.F.)	% of sales	Personnel in R. and D. (in million B.F.)
1	yes	450	3.5	15	210	4.0	0.5
2	yes	250	33	30	115 à 150	7.5	0.5 à 0.6
3	yes	200	3	8	100	1.2	0.5
4	yes	500	8	15	250	4.0	0.5
5 1)	No	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6 4)	yes	100	1.7	25	80	2.7	0.5
7 2)	No	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	yes	800	9	10	400	5.5	0.5
9 3)	yes	n.a.	n.a.	30	n.a.	12.0	n.a.
10	yes	3000	7.5	20	1.500	5.0	0.5

1) This firm has no formal R. and D. team although research and development alone or in cooperation is being done ; n.a. means not available, although we can state that for this firm research work is not large.

2) The headquarters of this firm are abroad. The local subsidiary does only a limited amount of development work. From other sources, its R. and D. effort (total company) is estimated at around 7,5 % of sales.

3) Firm found some measures difficult to estimate as part of the research and development personnel worked for several subsidiaries.

4) For firm number 6, the R. and D. personnel (not budget) is only, for applied research. The development personnel until now has been spread throughout the various technical divisions.

attaches to the best product. In the pharmaceutical industry for example, the best product alone can stay on the market even when its price is higher. In other branches as the metal products industry or even the electronics and communications industry other functions of the firm as for example marketing can play a greater role in the retention of a certain market share. Consequently, holding the 'leader' spot in research may not be so important for a firm in the latter industries as it is for one in the former.

An industry's pace of technological progress is the major factor influencing R. and D. efforts. It is clear for example that at present, the chances for major innovations are remarkably greater in the chemical industry as compared with the steel industry. That being the case and given the market rewards for an innovation, it is logical that R. and D. efforts are larger in the chemical than in the steel industry. In the sample covered, no firm belonging to the chemical industry broadly speaking has a R. and D. budget that was less than 4 % of sales ; firms in the steel and metal products industry on the other hand did not attain 3 %.

Often, smaller firms or firms that have recently entered a market are spending considerably more, relatively speaking, on R. and D. than do larger and more established firms. This is the case here for firms 2 and 9.

The fact that some firms spend considerably less on R. and D. than do others does not necessarily mean that they are mistaken. Indeed, after all R. and D. expenditure is related to profit expectations (however difficult it may be to estimate these) and expected profitability from R. and D. does differ from industry to industry.

We want to close this part with a comparison between the R. and D. effort in U.S. firms and those in our sample. This comparison is presented in table 2. The research efforts as a percentage of sales for the firms in the sample are not too different from their general American counterparts (provided U.S. figures have not changed much since 1961).

Table 2. Performance of Industrial Research and Development by Industry
(% of sales)

Industry	US (1)					Sample (2)
	1927	1937	1951	1957	1961	1969
Electrical equipment	.54	1.5	3.6	11.0	10.4	8.0
Chemicals	.42	1.1	1.5	3.5	4.6	5.0
Primary metals and products	.07	0.17	0.5	2.0	2.1	1.9

(1) Source : E. Mansfield 'The Economics of Technological Change' p. 56
Figures for 1957 and 1961 are not strictly comparable with earlier figures.

(2) Figures are averages of firms in respective sectors.

PART II. R. AND D. POLICIES

§ 1. General concepts

A lot of discussion is going on in academic circles about the aims of business enterprises and the implications for business behavior. It is in all likelihood safe to say that firms have multiple aims as well at a given moment of time as through time. Their overriding and longterm concern is generally the continuance and growth of the firm, often expressed in practical terms as the maintenance or increase in the market share.

Firms employ a variety of means to attain these goals. In this collection of means, research and development have become important especially in certain industries. Indeed, through research and development, a firm might gain a decisive edge over its competitor. Our empirical observations have led us to divide the firms interviewed in basically two groups (on the R. and D. score). In the firms of group I, research and development activity is considered vital for the firm, even in the short-run because of the pace of technological progress. The firms in group II will certainly not dismiss R. and D. work but maintain it or expand it more as a safeguard in the long run. It's short term role has then more a supporting character.

The above division in two groups does not imply that one follows a more correct course than the other. Indeed, whether a firm belongs to group I or II is to a considerable extent dependent upon the nature of its activities. Research and development projects can be looked upon as investment projects and thus should compete with other projects on the basis of expected profitability. When the firms in the different industries were asked about the profitability of R. and D., those in the

technologically dynamic industries rated its payoffs higher. So, it is only sensible that these firms have higher R. and D. budgets. If the reader would look back to table 1, we would bring firms 1, 3, 5 and 6 in group II, the others in group I (this division does not include firm 7 which is difficult to classify).

It may be interesting to note how an American investigator tried to explain the size of the R. and D. budget by means of a macro economic model [1]. According to this model, a firm sets its R. and D. expenditures in any given year somewhere in between last year's R. and D. budget and the desired level of R. and D. expenditures. The desired level would depend upon the firm's expectation regarding the average profitability of the R. and D. projects at hand, the profitability of alternative uses of its funds and the firm's size. The firm's speed of adjustment toward the desired level would depend upon the extent to which the desired level differs from the previous year's level and on the percent of its profits spent during the previous year on R. and D. This model fitted historical data well for eight firms on the chemical and petroleum industries. With still additional assumptions, it worked well for 35 firms in five industries (petroleum, chemicals, drugs, glass and steel). There is a priori evidence for the hypothesis that a similar model would fit the data well (if these were available) for the present sample of firms. How each firm fixes its R. and D. budget will be discussed soon.

§ 2. Specific policies and strategies

a. with respect to the R. and D. function

What are the professed aims of R. and D. individually in the firms interviewed ? The immediate answer was always : the continuance of the firm, the maintenance and possibly growth of the market share. Further questions were aimed at getting more specific information. Here follows a resume per firm of its

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1) E. MANSFIELD : The Economics of technological change ; Chapter 4, Industrial Research and Development, p. 62.

professed R. and D. aims.

Firm 1 [1] (belonging to group II) produces a line of now quite classical products in the metal products sector. It has through excellent performance in several fields assured itself a near monopoly position in many parts of the globe. Through mass production (which holds the prices of its products relatively low), maintenance of quality and good marketing, it estimates that it will maintain its market share. The role of the R. and D. group is thus in a certain way defensive, namely to keep up to date the technological knowledge with respect to the sector in question. Although it has a line of products with up to now a relatively long life cycle, it is aware that this may change. Therefore, while most of its work is of a product improving character, attention is being paid to new developments.

The budget for research and development is determined beforehand. It is normally so that costs incurred on behalf of accepted proposals (whose selection does not occur under the restraint of the budget) do not exceed the R. and D. budget. Quite some times, a research project is taken up because it was learnt that other firms in the same industry branch were working in the direction. Test marketing occurs predominantly with a few customers and preferably in an area where competition with an own product cannot be too strong. This suggests that R. and D. work is geared towards improvements of products for areas where one feels performance could be much improved.

Firm 2 (belonging to group I) is active in a certain sector of the chemical industry and has been absorbed by an American company. Research and development is considered the vital activity of the firm. The aim is to be a leader in the market through the development of new products as well as improved

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1) The random order of firms has been changed.

ones. It is only natural that they orient their research versus areas where they feel the competition has not secured too strong a position. But, although they limit somewhat the scope of their R. and D. activity, they are nevertheless willing to pursue any unexpected avenues that their research may open up. The R. and D. budget is not determined beforehand. One investigates all proposals and accepts all the 'favorable' ones no matter to what R. and D. budget this would amount. Usually, the R. and D. budget does not run out of control. As far as testing its new or improved products is concerned, the firm seeks out those situations, where testing is most adequately performed.

Firm 3 (belonging to group II) is a producer of services. There is no explicit purpose for R. and D. activities axcept the general goals of cost reduction and improvements for safety reasons. This occurs through R. and D. work of an evolutionary character.

Firm 4 again belongs to the chemical sector (and to group I). The aim of this firm is to obtain leadership in several areas through R. and D. work which became oriented and more directed in function of existing strong points, risk and size of the investment to be done, possible market shares and profit expectations. Although the research objectives are rather narrowly defined, one was willing to follow unexpected leads outside the delineated area if they promised to be profitable. The director of research in this firm told us the following about the stipulation of the R. and D. budget. "This budget is first established in accordance with corporate objectives. Of course there is a check so that this budget is compatible with resources, growth, increase of costs for the future... etc. This value is not subject to large fluctuations for a well managed budget is not very flexible. In case of some new ideas, which seem of fundamental interest to the company, special allocations may be granted."
The firm would resent being a 'me too' company. Thus it does not imitate

products just to be in the market too. If however, they feel they have a real chance of being the best seconds, they would consider launching research projects of this type. It is of course so that several firms will independently work on research projects along the same lines. Test marketing done in order to evaluate the acceptance of a product will normally occur in places where the risk of disturbing the market with this initial test is minimal.

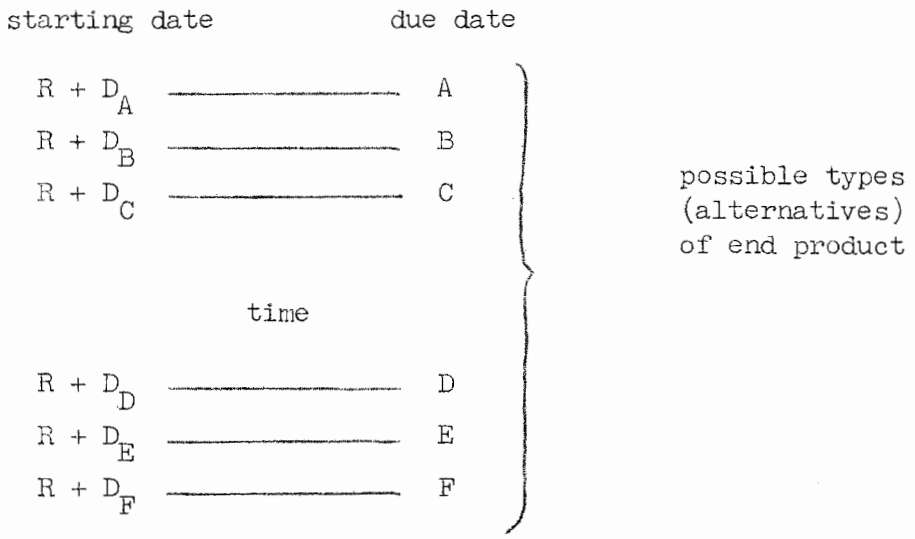
Firm number 5 belongs to the electrical equipment and communications industry and is part of an international organization (we classified it, after some hesitation in group II). The firm maintains that technological progress is so fast (in its sector) that patents can only give a very short-term protection or can be relatively easy circumvented. The R. and D. group has a dual role : on the one hand assure that the firm is aware as much as the competition of technological trends and possibilities ; on theother hand supervise the development of systems which obey as much as possible the restrictions put forward by clients. The R. and D. budget is not determined beforehand which again does not mean that all 'favorable' projects are accepted. Favorable projects may have to be rejected because of manpower limitations or because of the over-all financial possibilities of the firm. Thus we may interpret this as saying that if e.g. a rate of return of x % were generally considered favorable it may happen that only projects bringing a rate of return of at least (x + a) % are accepted. This policy is undoubtedly influenced by the international organization's top management which would seek to equalize the marginal returns in its several companies. Such a policy might give rise to large fluctuations in any individual company's R. and D. budget. Indeed, for the company under consideration the R. and D. budget could easily double or be sliced in half from one year to the next.

As far as imitation of R. and D. work between competitors is concerned, this company pointed out that this does not necessarily mean that ideas or

products are being copied but that several competing firms might work on the same idea because technological trends and possibilities are guiding the effort of all companies in the same direction.

Firm number 6 is the Belgian subsidiary of an international firm in the field of electronics and electrical equipment. The firm does not carry out applied research. Development personnel occupies itself mainly with the adaptation of systems conceived elsewhere in the international firm to the desires of the Belgian market. This type of work is considered a part of the marketing expenses.

Firm number 7 (classified in group I) has a few years back been created as a subsidiary of an international firm in the field of electronics and electrical equipment to produce a particular new product line. Already existing research and results on many components used in the new line made this policy quite logical. The firm as a whole is quite strong in applied research on electrical and electronic components and the subsidiary therefore concentrates on development work. The market is dominated by a giant competitor and the development group is asked to come on the market at the same time as the most important competitor with a product of comparable quality. This firm concentrates its attention on a very narrow product line and therefore the development budget is intimately linked with the type and quality of end product desired. Selection of a particular alternative means buying the particular development budget at the same time. The following sketch has been provided to help the reader in understanding the last two sentences.



Firm number 8 forms part of an international group in the broad area of chemistry. In accordance with its earlier work, the firm would belong to group II ; because of more recent developments, it can be classified in group I. A considerable part of the products manufactured by this firm is subject to changing fashion patterns. Until not so long ago, the R. and D. policy of the firm was defensive. Indeed, the aim was to follow the leader (and try to outdo him with respect to quality) in an established branch of activities, out of which one would not have ventured easily. The R. and D. policy now has changed in that it has become bolder, directed not only towards improvements in the more classical line of products but also towards discovery of new products. This is not unconnected with changes in top management positions and seems also be linked with greater technical confidence of the R. and D. team itself. Indeed, we were told that when the question ten to fifteen years ago was 'how to do things' it now boiled down to 'what to do'. Once an answer to the latter question is given, one was confident it could be done. In that respect one also felt that accomplishments by the R. and D. group of the leader could be matched

in a couple of years. The R. and D. group is vital in the short run not only because of the pace of technological development but also because of the demands put forward by changing fashion patterns. The R. and D. budget is a rather constant percentage of sales and more or less fixed in advance. The firm feels that this particular percentage norm is generally followed throughout the industry to which it belongs.

Firm number 9 (group II) belongs to the steel industry. There are no progressive objectives for the relatively large R. and D. activity. Top management is convinced that no startling discoveries can be made further in this sector and there is no effort at venturing outside the classical field. The task of the R. and D. group is to bring improvements to existing products to maintain high quality and also to realize cost decreases through the discovery of more efficient manufacturing processes (increased output, elimination of labor costs and social charges). The group is constant in size. The firm has through national and international formal or informal agreements obtained some kind of a protected market.

The 10^{th} firm (group I) belongs to the chemical industry broadly speaking. It is dominated in the international market by a giant company. The aim of the company and of the R. and D. group has typically been to bring as many products (materials) on the market as its big competitor. There is now doubt however that such a diversification can be maintained. The necessity of such a strong diversification also looks less desirable now as one sees smaller companies specializing in one particular item and capturing a very big chunk of the market even against the giant competitor. The firm is now of the opinion that too much emphasis has been laid on materials and that the future lies in offering materials, apparatus and services both to private and business users. Thus R. and D. efforts will be redirected to develop systems. Here again the company is following the leader who already

for some time was capitalizing on its sales of systems.

The R. and D. strategies and policies of group II are less progressive than those of group I. This may be with good reason. The pace of technological progress differs widely among the two groups and it is technological progress that affects the expected profitability of R. and D. projects. For a firm in the metal products sector e.g. it can be entirely justified that it is better to look for product improvements to beat the competition than for new products (which are relatively slow in coming). Or a firm might try to maintain a lead through other efforts than R. and D. if progress, even of an evolutionary nature proceeds very slowly. There is of course always the danger that even if progress in industry A proceeds slowly, faster developments in other industries might make at one point or another the products of A obsolete. Generally however, the tasks of R. and D. groups in group I are of a more urgent and more vital nature, certainly in the short and intermediate future than those of group II.

It is rather obvious that if a firm wants to follow and take part in rapid technological developments that its R. and D. budget must allow scope for flexibility. As expected the determination of R. and D. budgets in group I tended to be more flexible than those in group II. But as we have seen, flexibility can also arise because of other reasons, and in one of the firms discussed we suspect that capital rationing by the controlling organization was responsible for this.

Following and watching the competition are necessary activities of any firm. But again, these activities become more urgent and response is more dependent on the output of R. and D. groups in fast moving industries than in others. Also, when there is one firm claiming a major share of the market, the competition is more among the followers than against the leader. We heard

from some firms which find themselves in this position that they have no doubts about the capability of the leader to wipe them out but that there are a variety of reasons inducing him not to increase his market share beyond a certain point. Given this policy, it is the task of the smaller firms to be the most outstanding among the followers.

In any group of course, smaller firms are more vulnerable to miscalculations with respect to judgment of future technological development but especially so if the industry concerned undergoes rapid technological change. If e.g. firm number seven were not part of a larger entity, judgment of future developments and accurate timing would even be more crucial than they are now. Indeed, a failure in such circumstances might cause its demise whereas now the greater organization might keep it alive. Creation of this subsidiary has taken place in fact because of the existance of a group with diversified product lines, strong market positions and a variety of projects.

b. With respect to allocation for basic, applied and development work

What is for a given R. and D. budget the division between basic, applied and development work ? How much of this is carried on inside the firm, outside the firm and for what reasons ? What are the policies with respect to licensing agreements and cooperation in R. and D. ? In this section, we shall try to provide some answers based on the information that was obtained.

Basic research results in findings that cannot be patented and therefore is not of direct commercial value to any firm. Consequently, the amount of basic research undertaken varied from 0 to 10 % of the R. and D. budget. One can also surmise that in most instances more funds will go into development work than into applied research, because it seems logical that it is generally more expensive to develop a discovered application into a product

than to discover the application. The firms in the electrical equipment and communications industry spent from 80 to 90 % of the budget on development, the rest on basic and applied research. The firms visited belonging to the primary ferrous products sector and the chemical industry (except for drugs and medicines) devoted 60 % to development work and 40 % to applied and basic research. The percentage spent on applied and basic research in the drugs and medicine case amounted to 85 %. At least in the U.S. the funds spent on basic and applied research in this sector dominate those devoted to development. Moreover, the firm or firms in question here deliberately emphasize applied research to such an extent that 30 % of the applied research results get developed elsewhere whereas the figure for the opposite phenomenon is zero.

With the exception of a couple of firms in the electrical equipment and communications sector and the drugs and medicines sector, about 20 % of the applied research comes from outside and is developed inside the firms. About the same percentage of applied research findings inside the firms are developed outside.

We have already explained the case for drugs and medicines. With respect to the other exception, there is a considerable net influx of applied research results. This is simply a reflection of the fact that applied research on components occurs to a considerable extent in other subsidiaries of the parent firm or other firms in the holding.

The pattern of research and development expenses as it exists in the firms studied is not much different (except for a couple of cases as explained in the text) from the percent distrubition of funds for the performance of basic research, applied research and development existing in the U.S. The latter breakdown is given in table 3 on p. 19.

Table 3. Percent distribution of funds for the performance of basic research, applied research and development by industry, 1964. (U.S.)

Industry	Basic Research	Applied Res.	Development
Food and kindred products	9	47	44
Paper and allied products	3	36	62
Chemicals and allied products	13	-	-
industrial	m3	-	-
drugs & medicines	16	49	35
other	-	23	68
Petroleum	15	45	39
Rubber products	7	20	73
Stone, clay, glass	5	35	59
Primary metals	6	37	57
Primary ferrous prod.	7	-	-
Nonferrous and other	4	43	53
Fabricated metal prod.	3	23	75
Machinery	2	14	84
Electrical Equipment and communication	5	14	81
Motor vehicles and transportation equipment	3	-	-
Aircraft & missiles	1	16	83
Professional and scientific instruments	-	-	77
Textiles	3	50	47

Source : E. MANSFIELD, op. cit. p. 18

The firms seem to watch closely the exchange of research and development and want to have some balance between give and take. One of the roles of the R. and D. team as we were told by one firm explicitly was to improve on products or processes now used under license so that when the term of the agreement expired one's hands would not be bound by the licensing firm [1] . By virtue of the general policy just stated, this strategy must be quite common. The main reason for manufacturing under license is that the firm at the moment does not have the dimension, time, or resources to develop the component or product itself. Applied research results are developed elsewhere because one does not have the necessary production facilities or marketing facilities and it is decided that the firm does not want to add the product in question to its line. As we have already indicated on the occasion of the specific R. and D. policies, firms do not conscienciously pursue a policy of developing and selling product manufacturing rights. This does not mean that firms do not desire to have a restricted exchange of such rights. Most firms have agreements to that extent and such possibilities allow greater flexibility in research and increase efficiency. There exist even agreements to exchange production rights in packages but this occurred then (except in one case) among firms of the same group or holding company.

It may be worthwhile to register here the opinion of the leader of the R. and D. group of a large firm in the chemical industry. He made the observation that twenty years ago licensing agreements on major products or components occurred more frequently than now. This was a period when world production and trade was not yet so centralized among giant firms. As firms grew, there followed a period in which cooperative research efforts were in vogue. Now the establishment of international conglomerates, the internationalization of

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1) As a counter measure, firms giving licenses try to include a clause in the contract stipulating that all improvements become their property.

firms and markets and the struggle among the giants has made cooperation unnecessary and/or unwelcome. Licensing agreements now cover more minor components or occur in a major way with developing countries, who want production carried on inside their own frontiers.

Most firms have some research going on with universities, industrial research centers, other firms or even sometimes with clients for important applications. In general however, they want such research to be restricted to basic research, perhaps to applied research. They are against cooperation in product development. There were cases in the sample where applied and even basic research were excluded from any cooperative effort because of fear for leakage of secret information.

A firm may try to protect the results of its.R. and D. work through obtaining patents. A patent can be given to an invention which is novel and 'unobvious'. However, differences from country to country may arise as to exactly what part of the new process or product is protected. For example, in some countries the product can be patented ; in others only the particular process by which a product was obtained. We will not go further here into this matter. The great majority of firms informed us that patents offer little protection but that nevertheless they are taken as soon as possible in general. They offer little protection by virtue of the patent law itself or because of the marginality of the registered improvements (often the case for technologically not so dynamic industries) or the obsolescence to which they are subject because of fast technological progress. How one thinks about this is also influenced by the size of the firm and the industry one belongs to. There were firms (e.g. in particular sector of the chemical industry) who told us that it was difficult to circumvent a patent.

Patents are generally taken fast to exploit any gains that may be derived from product differention or the establishment of a temporary monopoly position. They are also important as recognition of work done so far. It may happen that a firm does not take immediately a patent on a discovery. This will be the case if one is convinced that more substantial findings lay ahead and that the competition is not keenly aware of the firm's work or success in this area or is too far behind to pose a serious threat. In this manner one can protect substantial more impregnable findings by not disclosing the initial successes. We encountered firms who indicated that patents had been taken too fast. For one firm, several patents offered no protection because they had been taken without full and detailed specifications. For another firm, the real profitable uses were only discovered a considerable time after the patent had been taken (the patent itself being impregnable) so that the time-span for sole commercial exploitation was severely shortened.

We can conclude this chapter on a note with respect to the freedom left to the individual researchers. We found three kinds of opinions. The majority opinion was to give the researchers some time (usually 10 %) during which they could work on whatever they liked to work. Other firms gave more freedom to researchers ; one went so far as to say that recruitment of research personnel and work assignment occurred on the basis of professed hobbies and that there were even persons who were totally free in their research ; their only assigned duty was to do a share of the more boring routine work. For a third group finally, research work was assigned strictly on the basis of the objectives of the firm and the R. and D. group with no 'free' time available.

The recruitment of researchers occurred, within the broad confines of discipines, more in function of quality than in function of specializations.

PART III. THE SELECTION AND EVALUATION OF R. AND D. PROJECTS

This chapter will be divided into two parts. First, we will discuss the evaluation and selection of specific projects. Second, we will deal with the overall evaluation of the R. and D. function in the firms.

§ 1. The selection of R. and D. projects

The selection of an individual R. and D. project occurs somewhat continuously through time. At the moment of birth of a certain idea, some selection already takes place on very general grounds. The surviving ideas are still surrounded by a mass of uncertainty both with respect to the definition of the concept as with respect to the potential for technical and commercial success. As work on an idea proceeds the uncertainty gets bit by bit removed up to a point where an economically meaningful evaluation can take place. The idea may now be rejected or accepted and receive a formal project status. Additional, more or less formal evaluations take place as the project develops, leading each time to a decision whether to continue or to stop. The sequel is devoted to a more explicit and detailed discussion of these procedures with some digression on the topic of birth of a new idea.

a. The process of developing a new idea

A new or improved product often finds its ultimate roots in basic research. Because industry makes only limited investments in basic research, it is exceptional that work proceeds continuously from basic to applied research to development. Usually, there is a significant lag between basic and applied research results.

Where do the ideas for research in the firm come from ? Instruction in the methodology of research is primarily in the hands of universities. So is most of the basic research. Applied research occurs in universities and industry. Because people in the firm most closely connected with research and scientific journals belong to the R. and D. group, we can logically expect that here most of the new ideas will be born.

Marketing departments do contribute to research and development work in the area of product improvements. The interest of the client in the development of an idea is conditioned by the nature of the product, the degree of complexity of the underlying concept and the circumstances in which he becomes confronted with it.

We assembled some data with respect to the origin of ideas for new or improved products in the firms visited. We noted that except in two cases, the R. and D. groups have been responsible for suggesting about 75 % or more of the number of innovations. This number is relatively high when compared with results from similar investigations in the U.S. (on the average 60 %). It may point to a strong degree of inward orientation of our industry [1)] . Marketing scores high (50 %) in two firms which are characterized by a high percentage of improvements on products incorporating considerable service for the client. In one of these firms (technologically dynamic), the marketing group stands very close to R. and D. In the other one, marketing could play such an important role as the task of the R. and D. group was defensive. In these sectors where the intellect and skill of the worker are important (e.g. metal products) ideas also come from the production department (in one firm up to 15 %).

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1) R. Vandenborre, J. Vandenbulcke and D. Vanwynsberghe ; The process of introduction and diffusion of quantitative research methods in Benelux firms, see part 2.

Ideas from outside come from universities, scientific publication, attendance of scientific meetings and contacts with competitors (freely or espionnage).

The originality and efficiency of the researcher can be fostered through a dynamic R. and D. management (policy and strategy), through allowing a certain degree of freedom in research, through internal and external contacts of R. and D. people and through an efficient organization of the R. and D. literature (purely scientific literature and collection of existing patents). Management's R. and D. policy and strategy and the individual freedom in research have been discussed in the preceeding chapter. One firm in the sample judged that the formal absence of an organigramme for the organization (although existing in the office of the president) was stimulating internal and external contacts. All firms agree that within the R. and D. department the functional organization is of a much higher importance than the hierarchical one. A key factor in the organization of research was the collection of R. and D. literature. Practically all firms had a strong attention for the establishment of an information retrieval system which would have to enable researchers to inform themselves about the latest technological innovations.

At the present time such systems are still in their initial phase. Perhaps it would be useful that industry research centers together with computer manufacturers take up the responsability for the design and organization of such retrieval systems.

Similar problems arise with respect to the updating of registered patents. Although few firms mentioned this, we learned that an organization exists (BIRPI - Bureaux Internationaux Réunis pour la Protection de la Propriété Intellectuelle) that proposes a catalogue (World Patent Index) of all registered patents classified by subject matter area.

The development of an idea to a new or improved product goes through several stages. In one firm, the successive stages were called pre-development, concept phase, definition phase, development preparation phase, detail design phase, prototype phase, serial production phase, installation phase and operation phase. In another firm, the break-down in phases occurred in function of the divisions directly involved in the launching of the new product. Thus for marketing we had approved marketing plan available, product introduction date and first order delivered. The technical division distinguished among the following steps : start development case, design model tested and full engineering release to manufacturing. And the manufacturing division broke the work down in full manufacturing drawings released, first production run started and first production delivery. Still another firm told us that a new or improved product progressed as follows : conception of the idea, laboratory, concept of technical instruments, pilot plant, production and marketing. These examples serve to illustrate that it is nearly impossible to put forward a general development path with common milestones, unless one aggregates the pieces or breaks down the entire path in a very few phases.

The relative number of new ideas accepted in an initial phase (e.g. pre-development) depends of course on the expected profitability. The expected profitability is however much influenced by the magnitude of the uncer-tainty. Uncertainty connected with suggestions as to product improvements is normally smaller than that connected with the creation of new products. Again, there are different degrees of uncertainty depending upon whether or not the new idea directly relates to a specific product and if the idea relates to a specific product, whether it is entirely new or relates to an existing product line. The more an idea relates to a group already in existence or the stronger its product improving character, the higher

its chances for acceptance. Thus we find that in firms with progressive R. and D. programs the relative number of ideas passing a preliminary screening tends to be smaller than in other firms just because the initial package presented contains many ideas with considerable uncertainty attached to them [1].

There is another important fact to be mentioned here, namely the nature of a firm's operations and thus of it's research work. This fact thus bears upon differences across industries. If research with respect to a certain idea can go far without necessitating specific expensive equipment, then many ideas may survive for a while but still the number of market successes may be small. As an illustration we can report here that a particular firm in the pharmaceutical industry told us that it would be difficult to create one successful product out of 400 new syntheses ; on the other hand, a firm in the electronics and communications sector mentioned a figure of one success per 10 new ideas.

Finally, we noted that as a general rule the relative number of projects moving from the applied research to development phases is larger than the amount moving from the birth phase to the applied research phase. Relatively few projects get stopped once they have fully entered the development phase.

The experience reported above is not unlike the experience of 51 companies in the U.S. as reported in D.D. Roman [2] . He gives the following graphical representation of the mortality of new product ideas by stage of evolution.

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1) On the other hand, the number of ideas submitted is also much larger.

2) D.D. Roman : Research and Development Management, Chapter 10, Project Selection, p. 207.

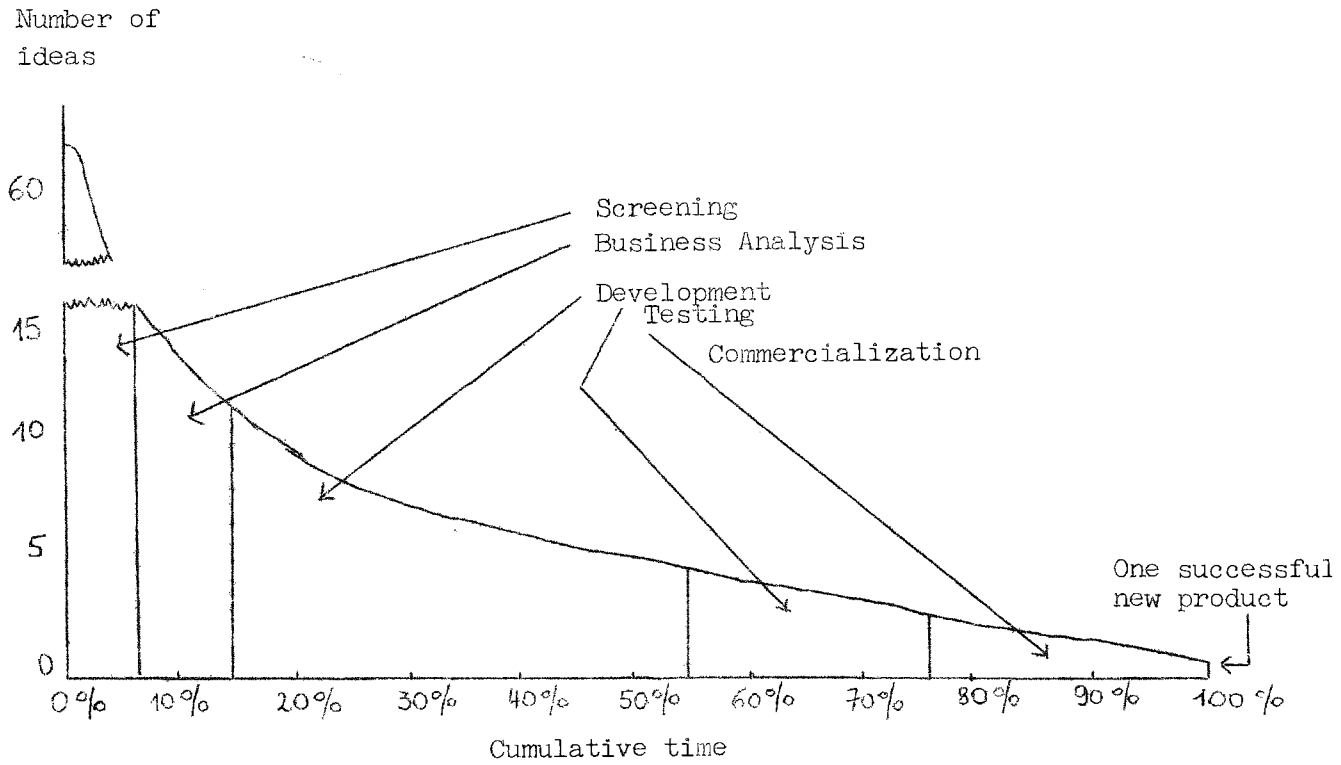

Fig.: Mortality of new product ideas, by stage of evolution, in 51 companies [1]

Already at the end of the development phase of the project the main focus shifts from the R. and D. function to the marketing function. This may give cause to certain frictions between R. and D. and marketing functions ; the marketing people trying to introduce the product as far as possible before the competitor can move in ; the R. and D. people still wanting to do a few additional tests to add some marginal improvements. The commercial introduction of the product signifies the end of the process. It is also necessary to register costs and returns fully for an a posteriori evaluation of the project.

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1) D.D. Roman : Research and Development Management, Chapter 10, Project Selection, p. 207

Undoubtedly, it will interest the reader to follow a couple of practical projects as they have developed throughout the different stages and to see the strategy and policies of the firms involved.
A certain firm in the chemical industry had watched over a period of time the research of a competitor with respect to an important new product A. The competitor had worked on the project off and on for a considerable length of time without much success. Some years back however, the rival seemed on the way to success and this information was not unknown to the management of our firm in question. A debate arose within the circles of top management whether or not to start R. and D. work on the potential product A. In the meantime, the firm had accidentally discovered product B but had failed in producing a product C that was complementary to B. Moreover, the potential market for product C did not justify a large R. and D. expenditure. The progressive elements in top management (which was at the time basically conservative) won out and an R. and D. project on potential product A was started. Moreover, because products A and C would be replacements of natural products which were of the same family, the search for A started along the lines of a search for C. This time, a successful product C was developed as a byproduct of the search for A. After a decade of R. and D. work, product A was introduced (later than the similar product of the competitor) with its own characteristics and of a high quality assuring it a prominent place in a lucrative market.

A second example concerns a firm in the electronics and communications sector. This firm was delivering several components for product A, manufactured by another large international enterprise. The growing technical strength of our firm in question, the dislike for the dependency on another firm for selling part of its products and the risks that such contracts might always be terminated have forced it to start work on product A itself.

In a final note here, we want to indicate that innovations, particularly in some industries, may arise because of the changing fashion demands. Such innovations, although they have incorporated new things technically have sometimes a tendency to disappear. In these circumstances, marketing departments often have the task to convince the public of the progress involved in and the necessity of acquiring the product.

b. Selection and evaluation

In view of the fact that we will deal here with selection processes in the firms it may be worthwile to give a quick survey of the best known techniques for investment selection.

The selection of projects by using the payback period is based on the time it is expected for an investment project to recoup its initial cost. The net present value criterion function is defined as the difference between the discounted future earnings and the current investment. The discounting factor is described as the cost of capital. The internal rate of return method uses that rate of interest which when applied to the various cash flows over the life of the investment, treating outflows as positive, and inflows as negative, gives a zero present value. All these methods are defined as economic approaches which are based on a detailed forecast of the profitability of each project proposal in terms of the investment required and the expected return resulting from it.

There are however some disadvantages in using these simple economic approaches especially the fact that they only take into account the criterion of profit maximization. There exists also a subjective approach which suggests certain factors (e.g. expected returns, uncertainty, continuance of firm...) in terms of which a project proposal might be

evaluated and derives a scoring model. The projects selected are those with the highest scores, the number of projects being determined by the constraint of total available budgets.

Among the more sophisticated models we may cite the risk analysis models which typically are based on a simulation analysis of input data in distribution form and which provide output distribution of such factors as rate of return, market share, etc. The method of mathematical programming is characterized by the use of O.R. techniques (e.g. linear programming, non-linear programming, dynamic programming) to optimize the selection of projects by maximizing the total value of the project proposals within the constraints of the total budget and other resources available. However, these latter optimization models, although being able to deal with more complex situations than the simpler economic approaches also offer the disadvantage of maximizing with respect to only one criterion.

From a theoretical point of view, there may be some reasons for a possible lack of use of formal methods (especially the objective approaches) : the interrelationships (dependency) among projects, the necessary continuous nature of project selection and review, the adequate treatment of risk and uncertainty, the exact selection of the interest rate of capital, the treatment of capital investment of which the outlays stretch over more than one budget period... etc.

As R. and D. projects have to be evaluated more than once during their life in the organization different policies can be followed [1]. One approach is to construct a single model which tries to consider and integrate the

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1) Moore J.R. and Baker N.R. ; Computational analysis of scoring models for R. and D. project selection. Management Science, Vol. 16, no. 4, december 1969, p. B 212 - B 231.

entire project life. In general, excessive data requirements, especially at research and explorating development, render such models difficult and expensive to use. Another approach is to propose a single model which can be used for each evaluation. Here also, excessive data requirements suggest that this policy will be difficult and expensive to operationalize. Finally, a third approach is to utilize structurally different models for the various evaluations. For example, a scoring model wcould be used in a preselection phase, an economic or constrained optimization model could be used for advanced and engineering development, and, in the case of new products, a risk analysis model could be used for the marketing decision.

We will now continue to discuss per firm interviewed, the specific procedures used in the selection of R. and D. projects. [1)]

Firm number 1 (group II) is in the metal products industry. The leader of the R. and D. group who is in direct contact with top management is responsible for the initial screening on the basis of the following criteria : can we acoomplish this work technically, can we devélop the concept without necessitating significant additional investment in productive capacity ; will the product once developed be reasonable close to the existing product line ? Ideas, that pass this stage are evaluated during their existence with the aid of scoring models. Committees (with representatives of Research and Development, marketing, production and top management) give scores to the projects on the basis of typical factors as expected revenues, expected market share, expected life cycle... etc. Projects with a sufficiently high score (higher than 13 on 20) are accepted ; projects with a score lower than 7 on 20 are rejected. Projects with scores between 8 and 12 are further discussed.

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1) The order in which the firms' selection procedures are discussed is the same as the one in the section 'R. and D. policies and strategies'.

There is a relatively large number of ideas in the first stage of the conception of the idea which are rejected. After the next stage of market and applied research a few more are rejected while very few projects are rejected during the real development stage. The average time between the selection of a new idea and the introduction of a resulting product on the market is between 2 and 5 years.

Firm number 2 (group I) is strongly research oriented and belongs to the chemical sector (broadly speaking). The director of the R. and D. group is at the same time member of the board of directors of the company. The firm belongs to a conglomerate and has a large degree of autonomy.

The firm drafts 3-year plans with annual individual and independent forecasts and semi-annual revisions. The annual forecast comprises the investments which the firm wants to make in any given year (capacity for new products and improved products, investments for cost reductions and strategic investments). In the latter category is included the R. and D. budget. The R. and D. group is split up in three subgroups in accordance with the project life span. Each subgroup drafts its own proposals for R. and D. work. These drafts are coordinated at the level of the R. and D. director who after consultation of the relevant persons decides which proposals will be accepted. The funds necessary to carry out the R. and D. work for the accepted ideas are taken up in the annual forecast figures.

The evaluation of the projects occurs in function of their impact on the balance between research and production and is further based on considerations with respect to commercial success and attainable technical quality.

Firm number 3 (group II) is a producer of services in the transport area. As we stated earlier, the R. and D. work is influenced by a continuous effort in the direction of more safety and higher efficiency in applied

processes. Although there is no formal coordination of the R. and D. work, it is clear that a ranking occurs in function of the technical complementary of the components which can be the subject of applied research. It happens that from several possible alternatives the least cost solution is selected without consideration of revenues.

Firm number 4 (group I) belongs to the chemical industry. Each division (product oriented) has its own R. and D. group besides a central laboratory where R. and D. takes place that is of a more general nature and as a result cannot be specifically assigned to anyone of the divisional R. and D. groups. Coordination for strategy, planning and commercial aspects is in the hands of the research director. He is responsible for drafting a five-year plan with respect to R. and D. that is in agreement with the general objectives of the firm. Each R. and D. group formulates its own research proposals. The R. and D. director checks if they are in line with the activities of the firm and correspond with its professed objectives. A first screening occurs on the basis of these criteria. The proposals made may directly point to products or they may not. In the latter case and if they were provisionally accepted, a study is made to investigate concrete fields of application. As the profit/cost ratio is still unknown (early stages), the research has to be launched with the objective of reducing the uncertainty about credibility of success, economical interest... . Check points are foreseen for this type of products. Unrealistic expenses for R. and D. should thus be avoided in due time. An idea under product form leads to a market study : estimation of expected price, size of market, share of market, competition, allied products... etc. Data are also assembled to enable one to make an estimate of the expected costs. On the basis of expected returns and costs, one computes present values of the projects, rate of return, cash flow, pay-back period. As we pointed out earlier, it is difficult to take into

account uncertainty. One nevertheless estimates the probability of success and derives in this way a probable rate of return (or a distribution of probable rates of return). Ranking and selection occur on these bases ; other qualitative criteria may in addition enter into the decision process. The decisions are taken by the R. and D. director together with the divisional R. and D. directors. The consent of top management is necessary for risky projects with high outlays.

The research portfolio is reviewed every two months. This is done to study as soon as possible the impact on the existing portfolio of changed circumstances.

Firm number 5 (group II) with activities in the area of electronics and communications has received extensive directives from the parent company with respect to the description, evaluation and selection of projects. Four detailed plans are made for each proposal : new product proposal, outline product plan, full product plan, R. and D. application and authorization. The birth of a new idea leads to a 'new (or improved) product proposal' plan. Such a product proposal plan contains the following material : an estimate of the potential markets and potential sales during the lifetime of the proposed product ; a series of financial indicators with respect to the new product as return on investment, average shop margin, average return on sales, average unit cost, unit sales price on home and export market, new capital investment, total development cost and manufacturing start-up costs ; a listing of most important competitors and clients ; and a specification of important milestones with respect to the start of the specific R. and D. program, start of the complete feasibility study, the engineering release to manufacturing and the product introduction date. A detailed study of the proposal must be preceded by an approval of the marketing, technical and manufacturing functions and also by the plant manager.

The outline product plan contains a marketing summary, a technical summary, a manufacturing summary and a general summary. Each partial summary is a resume of pertinent factors in that area (e.g. manufacturing costs and investments, new skills and facilities in the manufacturing summary ; R. and D. expenses, listing of patents and licenses in technical summary ; sales prospects, patterns and economic lifetime in the marketing summary). The general summary then contains the complete product financial analysis including expected market size, sales, net income or loss, sales of related products, new capital investment, return on investment, etc.

All divisions then work on the full product plan specifying the several important milestones in the execution of the product idea and giving details about the projected path to completion. This plan serves as a basis for the planning and scheduling of the activities, for the redaction of the annual business plan and the budget requests. Finally follows a R. and D. application and authorization with key financial and physical data to be approved by the technical staff, the production manager and the general technical director of the parent company.
The ranking of all projects is based on some key selection criteria as cash flow per unit of time and cumulative cash flow, payback period, return on investment, return on assets and return on sales. The financial department requires a certain minimum return on investment. Occasionally, projects are accepted with a much lower return on investment but with a short payback period (reasons hereto are that a project has become necessary to carry out other ones or that one wishes to serve and maintain a client). The technical division is pressing for more flexibility than that implied by the use of the payback period as selection criterion ; large projects by themselves require a larger amount of time for completion and recouping of investments. No estimates of connected uncertainty are made. This is partly explained by the fact that most projects are develop-

ment projects, the data of which are comparable with work formerly done and of which the total time span is not too large (2 to 3 years on the average).

Normally the number of acceptable ideas (after selection) does not result in an unrealistically large R. and D. budget. However, if there are many acceptable ideas available a choice will be made and an over-all schedule will be prepared to indicate the start of each project within the first years to come.

Firm number 6 is the Belgian subsidiary of a large international firm operating in the area of electronics and communication. The Belgian subsidiary does only a limited amount of development work. Their activities generally tend to adapt standard international programs to special problems of customers or prospects. Sometimes they may also aim at finding a solution to situations common to a whole sector of the activity if they were not yet studied in other countries.

Firm number 7 (group I) is a subsidiary of an international firm in the area of electronics and communications. The subsidiary is not the leader in its market and followers want to be ready with their new product when the leader is.

At a given moment in time management estimates the date at which the new product will have to appear on the market. Technological forecasting is used to help determine the characteristics the product should have. Given these requirements one determines what kind of results are already available and what type of applied research still has to be done. All necessary applied research on components then occurs in the so called development preparation phase. The end of this phase is fixed in time,

because the date for appearance on the market is fixed beforehand. All results available at the end of the development preparation phase are then used during the development phase proper, which is still divided in detail design phase and prototype phase. A full review takes place at the end of each phase with respect to costs, expected performance and consequently revenue and timing. The real selection process consists of :

- determining the future possible variations in the technological characteristics of the product with the help of technological forecasting ;
- determining the alternative R. and D. projects consistent with each substantial variation in the end product ;
- selecting initially some definite alternatives at the same time providing for the necessary latitude to make changes as long as possible in order to come up with the most appropriate end product.

It follows herefrom of course that planning procedures in the execution of the R. and D. work are of utmost importance.

Firm number 8 (group I) belongs to the chemical industry broadly speaking. It is only recently and because of a more progressive policy that one is forced to make a selection among projects under the allocated budget restraint. Formerly, allocated resources were ample to fund the worthwhile projects. A formal group has now been charged with the evaluation, selection and planning of potential R. and D. projects. Such a group also arose to provide more contacts among the directly interested groups in R. and D.

The selection of projects is heavily influenced by strategic considerations (will the firm try to be first on the market or wait a while to watch the behavior of competitors, some partially alien projects must be funded because one has important commercial agreements with those groups and one wants to follow progress in their fields). Relatively few ideas are

rejected because they often relate to specific products (which may or may not yet be in existence) and because informal discussions have already acted as a sort of a screening device.

The R. and D. group of firm number nine (group II) which belongs to the steel industry forms together with quality control and the technical-commercial service a subdivision of the division production. Research and Development consists of two groups : research-plants and the laboratories. Contact with clients occurs via the technical-commercial service. Occasionnally, the R. and D. group has contacts with the sales division (separate from technical-commercial service) whose department marketing has to furnish data for the evaluation of projects.

When a new idea is proposed, data are gathered from the marketing- , production- and financial departments with respect to expected cost, expected revenue, available budget, etc. The criteria for selection are vague and not well defined. The decision to accept a project is made by the directors of the commercial and technical divisions. A project once accepted is normally carried to completion. It is unclear according to what procedures a project may eventually be abandoned.

Firm number ten (group I) belongs to the chemical industry. A preliminary screening of ideas occurs in function of the overall aims of the firm and of the expected technological progress.

Once an idea must be taken into consideration a scoring model is used for evaluation. A number of variables are hereto taken into account as expected sales, expected life of the product, advantage over the competition, research costs, development costs, cost of pilot plant, manufacturing and production costs ... etc. Scores are rewarded

varying from -2 (least favorable) to +2 (most favorable). A description of the degree of uncertainty is added. Contrary to the usual practice in scoring models, no formal weights are attached to these scores but they are put next to each other for discussion and evaluation [1].
The firm has recently introduced an evaluation model to compare projects as to their expected profitability. This model is an index defined as the ratio between estimated discounted revenues and estimates discounted costs of the project. The discount factor used has been established after consultation and discussion with people of the financial division. They do not take uncertainty into account in this calculation but a note on the uncertainty connected with each project is added. In order to rank the selected projects for execution and in view of capital and manpower restraints, one employs the formula $\frac{A}{a}$, where A is the expected additional revenue per unit of time as compared with another project and a is the expected time for the realization of the project. Priorities (in execution) are defined in decreasing order of A/a. Continuing attention is being paid to the short term planning of each project in function of the overall R. and D. project plan.

Projects are periodically reviewed. Changes in the selection or ranking of projects may occur from the very moment that circumstances have changed.

A look at the selection process of the individual firm shows that firms belonging to group I use more formal procedures than those of group II. Indeed, for those firms where the R. and D. function plays a crucial role even in the short run, the question often is to select among the alternatives arisen because of technological progress and/or changed

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1) The normal procedure in a scoring model is as follows : Let y_j be the scores obtained on $j(1,\ldots n)$ factors on which one wants to base the evaluation. Then for each factor a weight w_j is fixed with $0 \leqslant w_j \leqslant 1$ and $\sum_{j=1}^{n} w_j = 1.0$. The overall score obtained by the project is then equal to $\sum_{j=1}^{n} w_j y_j$.

behavioral patterns. Firms with a more conservative R. and D. behavior usually do not generate such a number of projects that the allotted budget must act as a restraint. Moreover, they mostly work on improvements so that there is only a limited range of alternatives in contrast with these who are striving for greater diversification.

We have not encountered the use of sophisticated selection methods (e.g. mathematical programming). Even the number of firms using formal objective or subjective methods is restricted. However, these methods are used on a broader scale for the selection of investment projects falling outside the R. and D. domain. R. and D. projects seem to us to carry greater uncertainty and therefore, strategies can play a greater role in the selection process. Very few firms make use of a certain discount factor in the selection of alternatives. For those who did use it, the magnitude varied from 7 to 15 %. Conclusions could be drawn from this concerning the accepted profit rate in the several firms encountered.

The internal planning of selected projects with the help of less or more sophisticated tools (PERT, CPM) is then especially important when the time of launching the new product is crucial for success and one wants to keep the largest possible latitude as close as possible to that date.

The selection and planning of R. and D. projects is heavily influenced by the estimates made with respect to future technological developments. Very few firms are using these techniques in any formal way to have a grip on the problem of uncertainty. And we did not encounter any case where the results of technological forecasting were injected in a formal selection process. A spokesman for one company declared that they were engaging in some technological forecasting but that they never found in

Europe people ready to launch a Delphi method [1]. Another firm based technological forecasting on the number of phenomena invented and the rate of innovation. Potential progress was then found by introducing new technical possibilities.

A technological forecast is not a picture of what the future will bring. Instead, it is a prediction with a level of confidence in a given time frame of a technical achievement that could be expected for a given level of budgetary and manpower support [2]. Thus, trying to see what forces might change this prediction or where the main obstacles be and what they just are might be very useful exercises for firms to engage in.

§ 2. The overall evaluation of the R. and D. function in the firm

Can a firm determine how large the R. and D. function should be ? The economic answer is straight forward. But how does one compute the marginal return especially since returns follow costs with an unknown and very probably variable lag. One could use more specific and also more partial measuring rods as the determination of how well the output of significant innovations is correlated with the size of the R. and D. effort ; the percentages share of new products in the total sales say of the last five years ; the comparison between relative shares of new products and R. and D. budgets among competitors, ... etc.

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1) The method consists of having a group of experts in a chosen field name technical breakthroughs or inventions urgently needed and realizable within a certain time span. The experts are polled by written questionnaires, eliminating the open debate generally found in panel decision making. In a second round of questionnaires, participants are asked to give a time scale for achieving each of the items selected. They are also asked the reasons for their earlier opinions. These data are correlated and fed back to each with a request that he consider his earlier beliefs and submit new estimates. The result is usually some sort of concensus (M.J. Cetron and J.N. Johnson, Technological Forecasting in a dynamic environment, IEEE Transactions on engineering management, November 1969, volume EM-16, number 14).

2) M.J. Cetron and J.N. Johnson, op. cit. p. 190.

Throughout the firms visited, we have found no formal evaluation of R. and D. efforts. From the answers to questions raised on this aspect, it follows that indirect and informal evaluations do occur. Most firms indicated that in the intermediate future, they would maintain a rather constant proportion between sales and R. and D. effort. Some firms indicated that growth of the R. and D. function should occur in coordination with growth in other functions (balance of the functions in the firm). Finally, all firms were convinced that their relative R. and D. effort gave a good picture of the average R. and D. effort in the industry.

We have thus a somewhat strange situation. For some firms, the R. and D. budget is ample to fund all 'reasonable' projects. For others, the funds allowed may act as a constraint. As no deepgoing economic analysis occurs (it is still a question if this is possible), firms more or less stipulate an R. and D. budget on the basis of what the competition does. These mutual feedbacks result in a relative R. and D. expenditure that seems closely related to the scope for innovation in the different industries and that result in mutually tenable positions in the market.

Conclusions

1. One of the criteria for the measurement of the R. and D. effort is the percentage of sales devoted to R. and D. For the firms interviewed in this study, this figure varied from 1.2 % to 12 %. These percentages are determined in the first place by the nature of the industry (scope for technological progress, mutual feedbacks and market positions). They are quite alike for a given industry.

2. The R. and D. function is for every firm vital in the long run. In the shorter run however, the R. and D. group is more crucial for firms belonging to industries where technological progress is fast. These groups are also more aggressive in the sense that they pay greater attention towards the creation of new products. Firms in the other group spend relatively more effort for product improvements. These differences are also reflected more or less clearly in the R. and D. strategies and especially in the selection procedures. The industries often classified as 'classical' should pay more attention to the potential for competition arising from other industries.

3. All firms do as much as possible their own applied research and subsequent development. They have grown large enough to be able to afford it and estimate that competitive behavior forces them to do so. They also favor to have the possibility to buy applied research results for development and vice versa but on relatively minor components. Indeed, this possibility may increase the technical and commercial efficiency considerably. But they want such exchanges to be relatively restricted and favor the position of being able to seel applied research than having to buy it.

4. The firms visited practiced basic research to a very limited extent. Basic research was also done through contracts, the holding company, the parent company or a cooperative research center. Firm resent however that cooperative research centers engage in development work. These centers could do important work in the future by designming and realizing retrieval systems for scientific literature.

5. The recruitment of R. and D. people occurs, within the broad confines of disciplines on the basis of quality rather than specialization. The percentage university graduates reaches a maximum of 30 for the firms under study and research employs more university graduates than development. The individual researcher is generally given only a limited amount of freedom.

6. The source of new ideas for R. and D. is perhaps more than in the U.S.A. the R. and D. department. This may point to a stronger production orientation of our firms. The second source of ideas is the marketing department.

7. The speed with which patents are taken depends considerably on how close one thinks a competitor stands to patenting the same of a similar product or process. Usually, patents are taken as fast as possible with the connected risk of an insufficiently detailed description of the concept for good protection or an insufficient knowledge of the uses of the conceived product or process. The more difficult it is to circumvent a patent, the stronger industrial espionnage.

8. No sophisticated methods are used for the evaluation of R. and D. projects. Selection and evaluation occur with the help either of formal objective or subjective simple models or in a more informal

manner. Very little is done to get a grip on the uncertainty problem. Technological forecasting, which could result in considerable information with respect to uncertainty is in its very beginnings. Although all firms looked somewhat at the same criteria, differences in the details of their specification and evaluation and differences in the models used could result, for the same project and the same circumstances, in acceptance in one firm, rejection in another.

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